ANCs for ${}^{14}N \to {}^{13}C + p$ and the Astrophysical S-factor for the ${}^{13}C(p,\gamma)^{14}N$ Reaction

A. M. Mukhamedzhanov, A. Azhari, V. Burjan[1], F. Carstoiu[2], C. A. Gagliardi, V. Kroha[1], Sattarov,
X. Tang, L. Trache, and R. E. Tribble
[1]*Institute for Nuclear Physics, Prague-Rez, Czech Republic*
[2]*Institute for Physics and Nuclear Engineering, Bucharest, Romania*

In our previous report we presented preliminary results of the R-matrix analysis of the experimental data [1] of the astrophysical factors for the ${}^{13}C(p,\gamma)^{14}N$ reaction. This **r**eaction is one of the important reactions of the CNO cycle. The R-matrix method allows us to treat in a consistent way, the resonant and nonresonant contribution, avoiding double counting. The R matrix nonresonant amplitudes are parametrized in terms of the asymptotic normalization coefficients (ANC's) measured by us [3, 4]. The details of the analysis are given in our previous report. In this report we present the final results of the analysis. We find that the nonresonant captures are important to describe the data. Their effect is amplified due to interference with the resonance amplitudes. Note that 6 of 7 transitions to the bound states measured in [1] are reproduced using the ANC's determined in our previous works [3, 4]. We determined more accurately the uncertainties of the fits to all bound states.

1. The best fit for transition to the ground state gives $S(0) = 5.36 \pm 0.71$ keVb. The contribution of the second and third resonances and background pole are taken into account.

2. The fits for the transition to the first excited state gives $S(0) = 0.32 \pm 0.08$ keVb. For the first excited state, for which the two measurements using the ${}^{13}C({}^{14}N,{}^{13}C)^{14}N$ reaction [3] and the ${}^{13}C({}^{3}He,d)^{14}N$ reaction [4] gave the conflicting results. The fit to the experimentally measured S-factor for the ${}^{13}C(p,\gamma)^{14}N$ capture allows us to state that the ANC for the first excited state, $C_1^{\,2} = 8.9$ fm^{-1} determined in [3], is preferred.

3. The fits for the transitions to the second and third excited states gave $S(0) = 0.88 \pm 0.12$ keVb and $S(0) = 0.33 \pm 0.07$ keVb, correspondingly.

Note that transition to the third excited state has not been resolved in the ${}^{13}C({}^{14}N,{}^{13}C)^{14}N$ reaction [3] and the ANC, $C^2 = 12.66 \pm 0.89$ keVb, has been determined only from ${}^{13}C({}^{3}He,d)^{14}N$ reaction [4]. We find that the best fit gives the ANC $C^2 = 33.0 \pm 4.0$ fm $^{-1}$, i. e., 2.6 larger than the ANC determined in [4].

4. For the fourth and fifth excited states, our best fit gave $S(0) = 0.045 \pm 0.009$ keVb and $S(0) = 0.77 \pm 0.09$ keVb, correspondingly.

5. The fit for transition to the sixth excited state gives $S(0) = 0.031 \pm 0.007$ keVb.

Finally, for the total S factor we get $S(0) = 7.7 \pm 1.1$ keVb. This is in excellent agreement with $S(0) = 7.64$ keVb determined in [1]. Hence, we confirm the higher value of the astrophysically important S(0)-factor for the

$^{13}C(p,\gamma)^{14}N$ capture. This means that there is less ^{13}C available for the reaction branch $^{13}C(\alpha,n)^{16}O$, generating correspondingly fewer neutrons for the subsequent s-process nucleosynthesis. Our calculated reaction rates for temperatures $T_9 \leq 0.1$ on average are 17% higher than those given in compilation [5].

The good description of experimental data by our calculations is another test of the indirect method which uses the ANC's determined from peripheral transfer reactions to extract astrophysical S-factors.

References

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